Computer-Simulated Building Energy Consumption for Verification of Energy Conservation Measures in Network Facilities

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A computer program called ECPVER (for Energy Consumption Program – Verification) has been developed to simulate all energy loads for any number of buildings. The program computes simulated daily, monthly, and yearly energy consumption, which can be compared with actual meter readings for the same time period. Such comparison can lead to validation of the model under a variety of conditions, which allows it to be used to predict future energy saving due to energy conservation measures. Predicted energy saving can then be compared with actual saving to verify the effectiveness of those energy conservation changes. This verification procedure is planned to be an important advancement in the Deep Space Network Energy Project, which seeks to reduce energy cost and consumption at all DSN Deep Space Stations.

I. Introduction

Shortly after the 1973 oil embargo, the Goldstone Deep Space Communications Complex (GDSCC) initiated an energy management program following NASA guidelines. The Goldstone Energy Project formally started on July 1, 1975, with the objective of reducing the consumption of purchased energy by 50 percent within 10 years of the formal starting date. Total energy consumption during fiscal year 1973 was to be used as the baseline for calculating energy savings. In July 1977, a similar project was formally begun with the same goal for the overseas Deep Space Stations. The project then became known as the DSN Energy Project.

The project plan for the near term has involved, among other things, the reduction of energy consumed in existing equipment and building configurations. Before energy savings could be realized, particularly from major equipment modifications, a reliable model capable of predicting energy consumption under various loading and operating conditions was needed. A computer program called ECP, for Energy Consumption Program, was first developed for this need in late 1977. The design and utility of ECP has been described in Refs. 1 and 2. Briefly, the program is designed to simulate all energy loads of a particular building and to compute the thermal and electrical energy consumption. It can be used to (1) monitor hourly, daily, monthly and yearly energy consumption, (2) identify and itemize energy consumption by equipment categories, and (3) predict future consumption levels. Since many equipment modification decisions must be made based on the results of the program, the accuracy of the model is of prime importance. The ECP program is continually being refined, updated and checked for flexibility, accuracy and additional features that are supportive to the design engineers.

II. Need for Verification

The importance of the accuracy of any energy consumption model for building load simulation cannot be understated, and where possible the ECP model is compared with actual meter readings for validation and verification. However, many of the buildings at the DSN Complexes are not metered individually. Several buildings are often connected to a single meter. This can be seen, for example, in Fig. 1, which shows the electrical power and liquified petroleum gas (LPG) distribution systems with presently existing electrical and gas meters at DSS 12 at Goldstone. In order to compare simulated consumption with actual meter readings where buildings are not metered individually, a modified version of ECP is necessary to simulate more than one building at a time. The modified version (given the name ECPVER, for Energy Consumption Program – Verification) has been developed for this need.

In addition to accurately predicting future energy consumption levels due to planned conservation changes in equipment and operational procedure, the verification program is flexible enough to assist in identifying the causes behind unplanned consumption changes. These include unusual change due to (1) exterior environment such as outside air temperature, pressure, humidity, wind speed, cloud cover, etc., (2) interior building environment including occupancy levels, humidity, and lighting hours, and (3) equipment operation or procedure such as downtime or emergency use. It is necessary to track and explain these unexplained load changes in order to determine the accuracy of the model under all possible conditions that may arise.

III. Description of Verification Model

The verification model (ECPVER) is designed to sum the energy consumption results for any number of buildings as needed for comparison with a particular meter configuration. For example, if four buildings are connected to a single meter, the simulated energy and cost profiles during a selected period of time are summed and printed for that meter. Input data have been grouped into three separate cataloged files for the three geographic locations: Goldstone, Canberra, and Madrid. Each cataloged file contains four program files identifying (1) all buildings included in the Complex by name, (2) all buildings included at each individual site, (3) all buildings monitored by each specifically numbered meter, and (4) each building with complete coded data needed by the program to simulate energy loads and consumption (see Ref. 2). The verification program can be run by declaring a Complex, site, meter, or single building option, and then identifying the site number, meter number, or building name. The program then prints out the summation of thermal and electrical consumption for all buildings included in the chosen option. A flow chart of the program logic is sketched in Fig. 2.

Implemented energy conservation changes produce two streams of data as shown in Fig. 3 which, when compared, lead to analyses of the effectiveness of those energy conservation measures. Multiple passes cause the model to more closely approximate actual consumption by allowing for update and also tend to minimize energy consumption by providing design feedback for further changes.

IV. Application

To date, only a few runs have been made for the DSN Complexes. From these runs, preliminary verification analyses have been made and some update of the model has been effected. The major portion of the verification effort at Goldstone is awaiting the completion of the energy audit, which will yield updated information for all the building loads at the Complex. For the Complexes in Spain and Australia, the energy audits are completed for the major energy consumers. However, none of the overseas sites are now equipped with multiple watt-hour meters. A plan for installing several watt-hour meters and related logging instruments at both the Madrid and Canberra Complexes is underway. The verification procedure will proceed when their installation has been completed.

Another important application of the ECPVER program, not related to verification, is identifying total energy consumption by categories. The program output itemizes building energy consumption by the following categories: (1) heating equipment, (2) cooling equipment, (3) electric accessories, (4) thermal-powered accessories, (5) incandescent lighting, (6) fluorescent lighting, (7) electrical equipment, (8) mechanical equipment, and (9) thermal equipment. By applying the model for all the buildings at a particular site, the total energy consumption can be itemized on a percentage basis for each of the categories mentioned above. This has been tested for all the overseas sites. As an example, it is now known that cooling presently consumes approximately 19.5 percent of all energy used at DSS 61/63, as shown in Fig. 4.

V. Summary

The effectiveness of energy conservation measures at all DSN facilities needs to be determined prior to and after implementation as accurately as possible. A computer program (ECPVER) has been developed to accomplish this verification by providing for direct comparison of actual meter readings with computer-simulated values. The verification program is planned to be an integral part of the DSN Energy Project and will be updated as more data from planning, engineering and operational sections become available.

References

1. Stoller, F. W., Lansing, F. L., Chai, V. W., and Higgins, S., "Energy Consumption Program – A Computer Model Simulating Energy Loads in Buildings," in *The Deep Space Network Progress Report 42-45*, pp. 288-293, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1978.

2. Lansing, F. L., Strain, D. M., Chai, V. W., and Higgins, S., "The Updated Algorithm of the Energy Consumption Program (ECP) – A Computer Model Simulating Heating and Cooling Energy Loads in Buildings," in *The Deep Space Network Progress Report 42-49*, pp. 107-115, Jet Propulsion Laboratory, Pasadena, Calif., February 15, 1979.

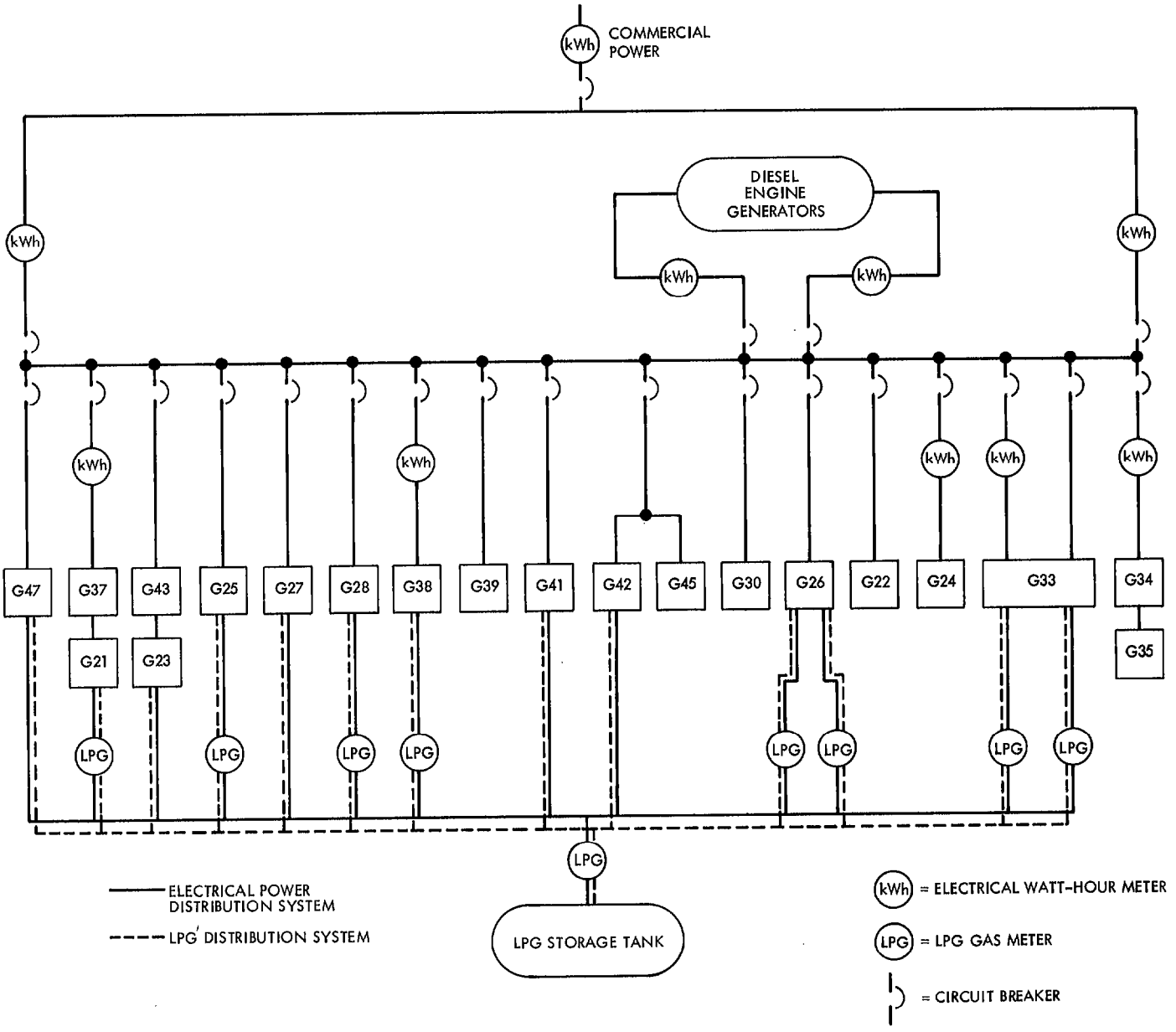

Fig. 1. Electrical power and LPG distribution systems at DSS 12

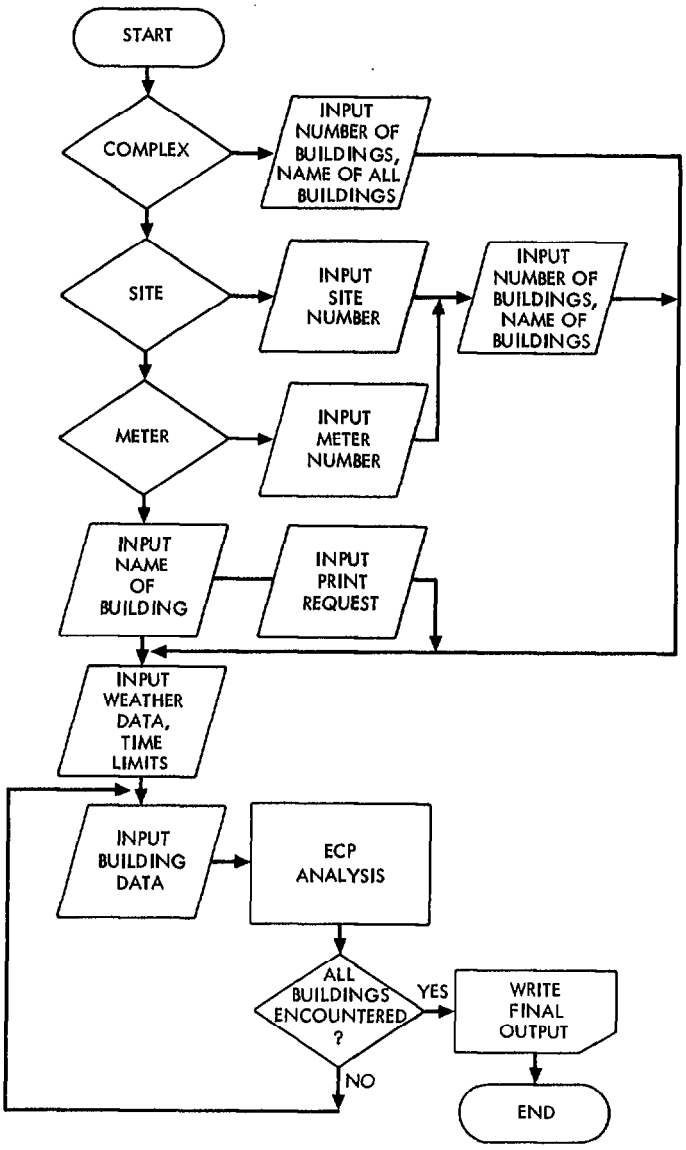

Fig. 2. Flow chart of ECPVER

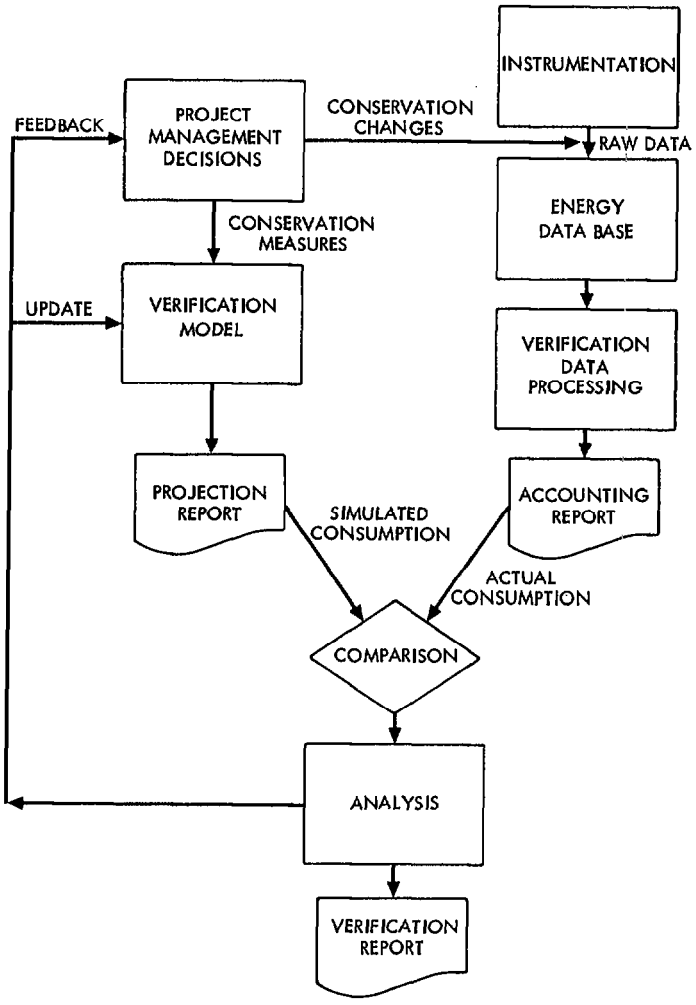

Fig. 3. Verification flow diagram

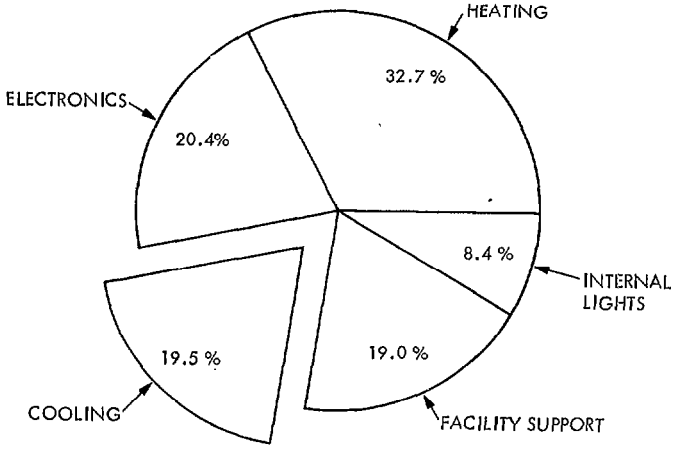

Fig. 4. Itemized DSS 61/63 consumption